ELECTRON BEAM ION SOURCE

WBS 1.5 Power Supplies

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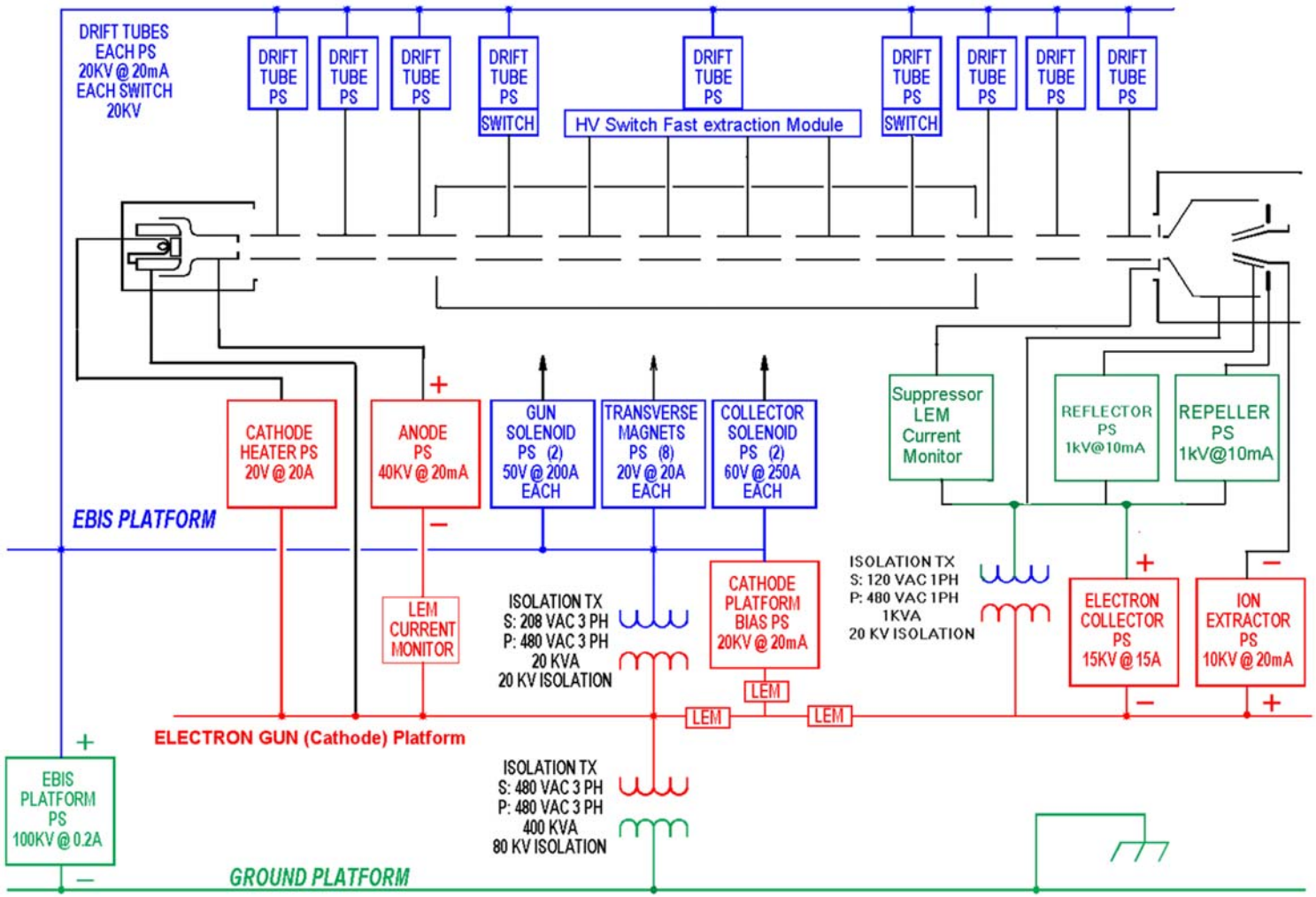
EBIS Platform Power Components



Platform Power – Isolation Transformers

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Design Considerations

- Provides isolated power to the EBIS, Cathode, and Reflector platforms
- Low inter-winding capacitances minimize current requirements of offset supplies and improves tracking between platforms

Function	Primary	Secondary	Power	Isolation	Cost
Electron Gun Platform	480 VAC, 3φ	480 VAC, 3φ	400 kVA	100 kV	-
EBIS Platform	480 VAC, 3φ	208 VAC, 3φ	20 kVA	20 kV	$ 15.0 k
Suppressor Platform	480 VAC, 1φ	120 VAC, 1φ	1 kVA	20 kV	$ 5.0 k

EBIS Platform – PS Operation / Sequence

- Fill – The EBIS platform PS is off. This allows the EBIS to be filled from one of the two external ion sources, which are at ground potential. Having these sources at ground potential makes their maintenance easier.

- HV Pulse – The EBIS platform is pulsed to 100kV. As all other platforms are reference to the EBIS platform, they all rise as well. Once at full voltage, the flattop will be maintained for a minimum of 40 μsec.

- Extraction – Some of the drift tube power supplies are pulsed by fast solid state switches to extract the ion beam from the EBIS.

Platform Power – Voltage Offset

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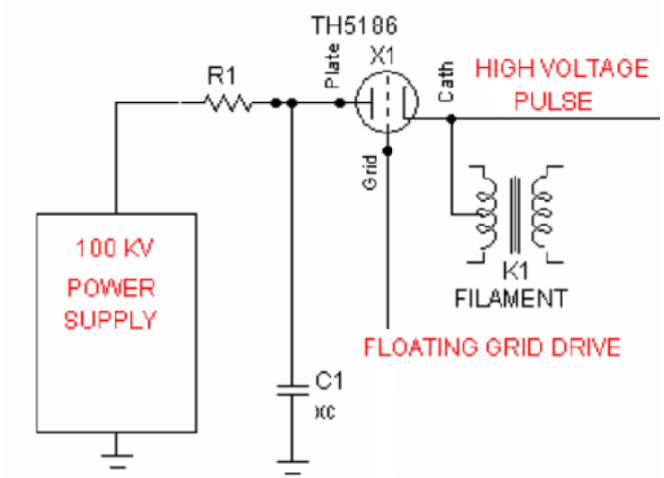
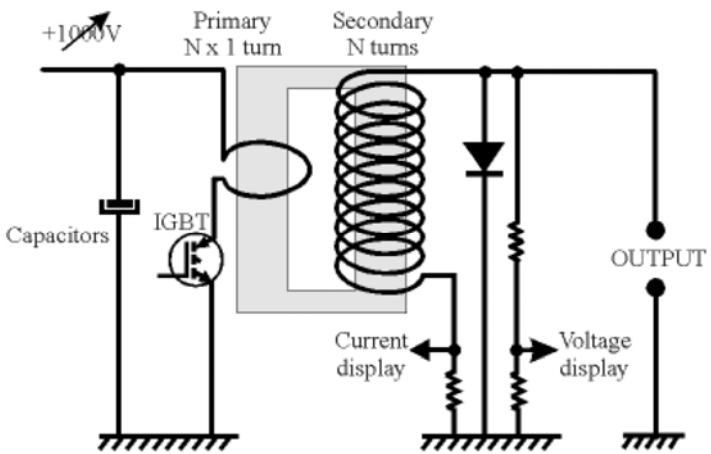
Design Considerations

- EBIS Platform PS: Provides pulses with two levels of amplitude with flat-tops of 10 – 40 μs widths. Either an tetrode or IGBT design could be used based on detailed design (see next slide).
- Cathode Platform PS: Static offset to the EBIS platform supply
- Reflector Platform: Static offset to the Cathode platform by the electron collector power supply, not a separated offset supply

Function	Voltage	Current	Operation	Cost
EBIS Platform PS	100 kV	0.2 A	Pulsed	$ 78.7 k
Cathode Platform PS	20 kV	20 mA	DC	$ 13.4 k

EBIS Platform PS – Design Trade - Offs





Tetrode

- Continuously variable rise & fall times if needed to control tracking between platforms
- Modulation by tube in linear operation
- Integrated at BNL

IGBT

- Fixed rise and fall time
- Modulation by dual primary windings with independent DC sources - IGBT in switch mode
- Purchased part

Platform PS – Bias & Magnet Supplies

These supplies are all operated as static power sources, except the cathode heater, which is a ramped, current regulated supply.

Function	Voltage	Current	Power	Qty	Unit Cost
Cathode Heater	20 V	20 A	400 W	1	$ 9.0 k
Anode	40 kV	20 mA	800 W	1	$26.8 k
Reflector	1 kV	10 mA	10 W	1	$ 2.2 k
Repeller	1 kV	10 mA	10 W	1	$ 2.2 k
Electron Collector	15 kV	15 A	225 kW	1	$ 200 k
Ion Extractor	10 kV	20 mA	200 W	1	$ 5.0 k
Gun Solenoid	50 V	200 A	10 kW	2	$ 9.5 k
Collector Solenoid	60 V	250 A	15 kW	2	$ 9.5 k
Transverse Magnets	20 V	20 A	400 W	8	$ 2.5 k

Platform Power – Drift Tubes

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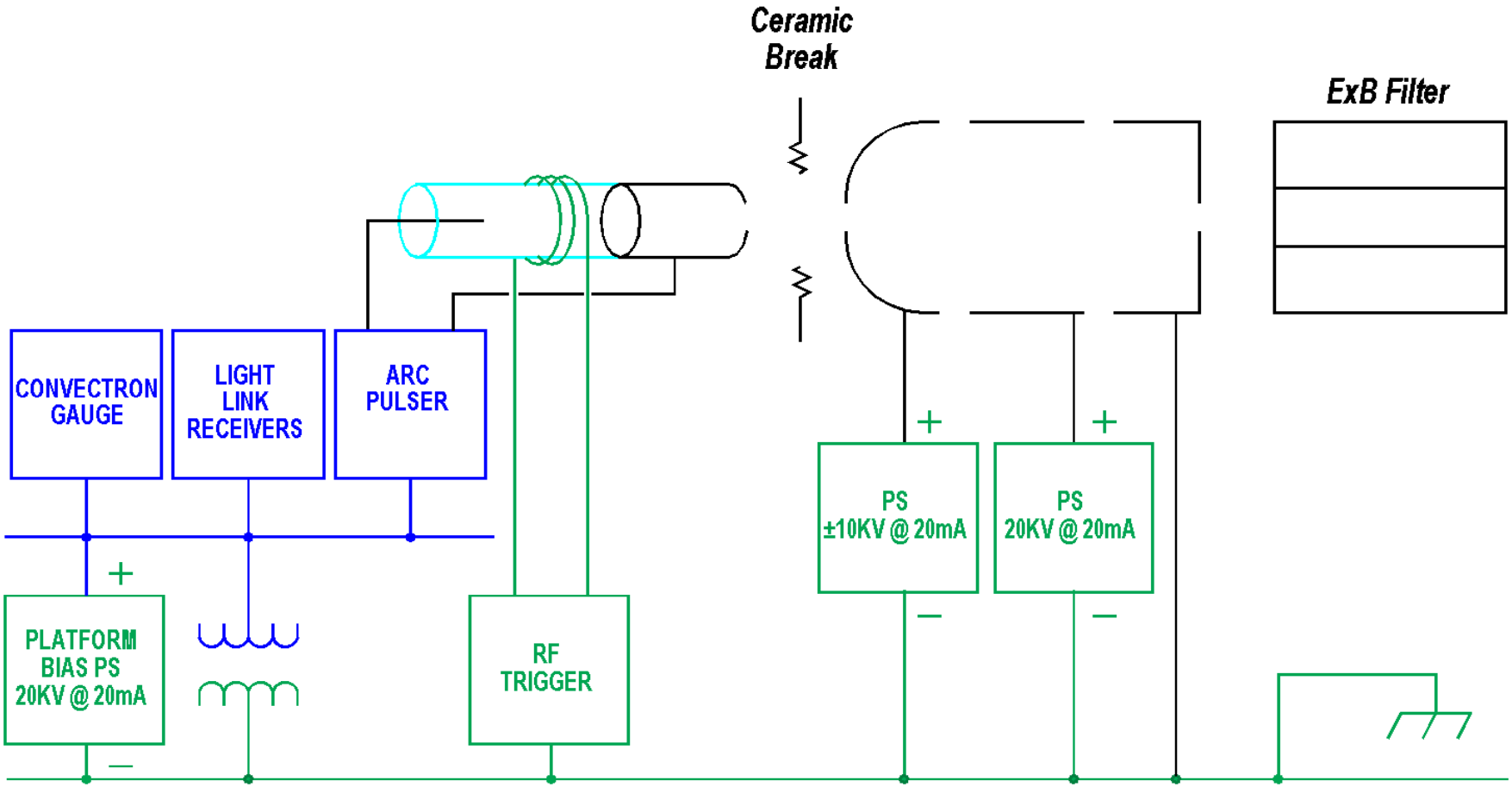
Design Considerations

- The power supplies are operated statically. The output waveform is created by the fast HV switches.
- These waveforms are monitored by the high speed (100 kHz) version of the Power Supply Interface.

Function	Type	Ratings	Qty	Unit Cost
Drift Tube PS	Trek 20/20	20 kV, 20 mA	7	$ 13.4 k
Fast HV Switch	HTS 20103 GSM	20 kV, 30 A	3	$ 3.5 k

External Ion Injectors & LEBT



Ion Source Power Elements (Two Units)

- Bias for the Pulser Platform
  - Bias PS: 20 kV @ 20 mA, DC supply ($ 13.4 k)
  - Isolation Transformer: 120 VAC to supply power to the Arc Pulser and electronics on the platform ($ 2.5 k)

- Arc Pulser ($ 15.0 k)
  - Storage Capacitors: Provides pulse energy
  - Variac & Step-Up Tx: Charging supply for the capacitors
  - Heater PS

- RF Trigger Supply ($ 4.0 k)
  - Initiates discharge

Ion Source Transport Power Elements (Two Units)

- Static Supplies
  - Extractor PS: 10 kV @ 10 mA ($ 4.0 k)
  - Lens Supply: 20 kV @ 20 mA (2 units @ $ 26.8 k ea)

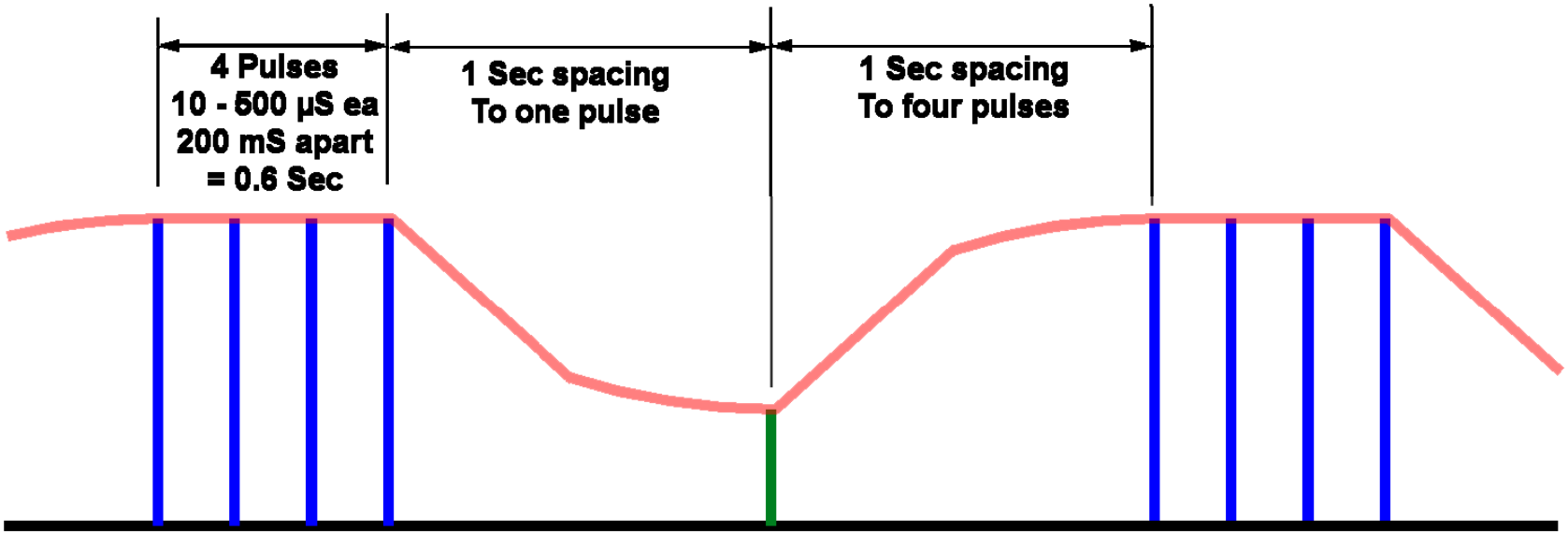
- Steering
  - Fast Electrostatic Bend: 4 kV @ 1 mA (2 units @ $ 16.0 k ea)
  - ExB Deflector: +/- 750 V @ 60 mA ($ 1.2 k)
  - ExB Magnet: 10 V @ 4 A DC ($ 0.2k)

LEBT Power Elements

- Steering / Switching
  - Beam Line Steerer: +/- 750 V @ 60 mA (8 units @ $ 1.2 k ea)
  - Fast Electrostatic Bend: 4 kV @ 1 mA (4 units @ $ 8.0 k ea)
  - Electrostatic Lens: 30 kV @ 20 mA (2 units @ $28.0 k ea)

- Matching
  - Pulsed Solenoid: 2,000 A @ 100 V ($ 75.0 k)
  - Current Wave Period: 2.6 seconds

Pulsed Operation of Magnet Power Supplies



- The LEBT solenoid, MEBT quads, LINAC quads, HEBT quads, and HEBT dipoles are all pulsed with this wave shape.
- The L*di/dt requirements of this current wave shape for the magnets require higher voltages on the power supplies, especially the HEBT big bend.

Sample Pulsed Magnet PS Calculation

This is an example of how the power supply for the big bend dipoles at the end of the HEBT were determined to require 250 V for the pulsed waveform.

- Magnet Parameters: R = 7.6 mΩ, L = 10 mHy, Imax = 3,285 A
- Inductive Voltage: Maximum slew rate of full current in 0.5 seconds. Then, V_L = 10 mHy * 3,285 A / 0.5 sec = 65 V.
- Magnet IR Drop: V_R = 3,285 A * 7.6 mHy = 25 V
- For Two Magnets with 25% overhead:
  V_M = 1.25 * 2 magnets * (65 V + 25V) = 225 V
- Cable Losses: Run from the LINAC to the series connected magnets. Assume round trip losses of 25 V.

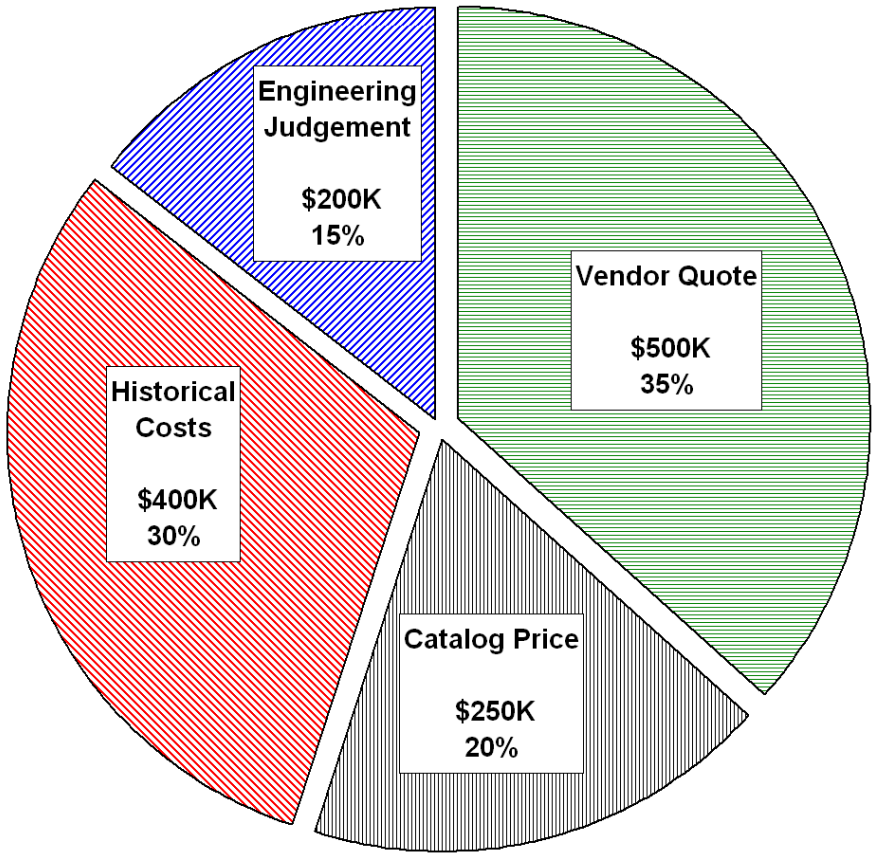
MEBT, IH LINAC, & HEBT

- MEBT
  - Quads: 450 A @ 20 V, Two quadrant in voltage (4 units @ $ 18.4 k ea)
  - Steerers: 15 A @ 35 V, Four quadrant (4 units @ $ 4.5 k ea)
- LINAC
  - Quads: 450 A @ 20 V, Two quadrant in voltage (6 units @ $ 18.4 k ea)
- HEBT
  - Big Bend Dipoles: 3285 A @ 250 V, Two quadrant in voltage ($ 150.0 k)
  - Quads : 25 A @ 35 V, Two quadrant in voltage (4 units @ $ 4.5 k ea)
  - Steerers : 15 A @ 35 V, Four quadrant (12 units @ $ 4.5 k ea)

WBS 1.5 Power Supplies

- Major procurements:
  - EBIS Electron Collector PS
  - Pulsed High Current PS: LEBT solenoid & HEBT big bend
- Deliverables:
  - Everything here except Electron Gun Platform isolation transformer (400kVA).

WBS 1.5 Power Supplies – Cost Summary



Basis of Material Costs

Cost Distribution Direct FY'05K$		
	Material	Labor
EBIS Platform	$ 530	$ 80
Ext. Injectors & LEBT	$ 330	$ 50
MEBT, IH LINAC & HEBT	$ 490	$ 65
Totals	$ 1,350	$ 195

Total Cost $ 1,545K

WBS 1.5 Power Supplies

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- **Estimated Cost**

WBS	Description	Direct FY'05K$			
		Mat'l	Labor	Contingency	Total
1.5	Power Supply Systems	1350	195	$400 (26%)	1945

- **Labor hours/equivalents**

Resource Category	estimated hours
Engineer	1,475
Designer	975
Total	2,450
Full Time Equivalents	1.4